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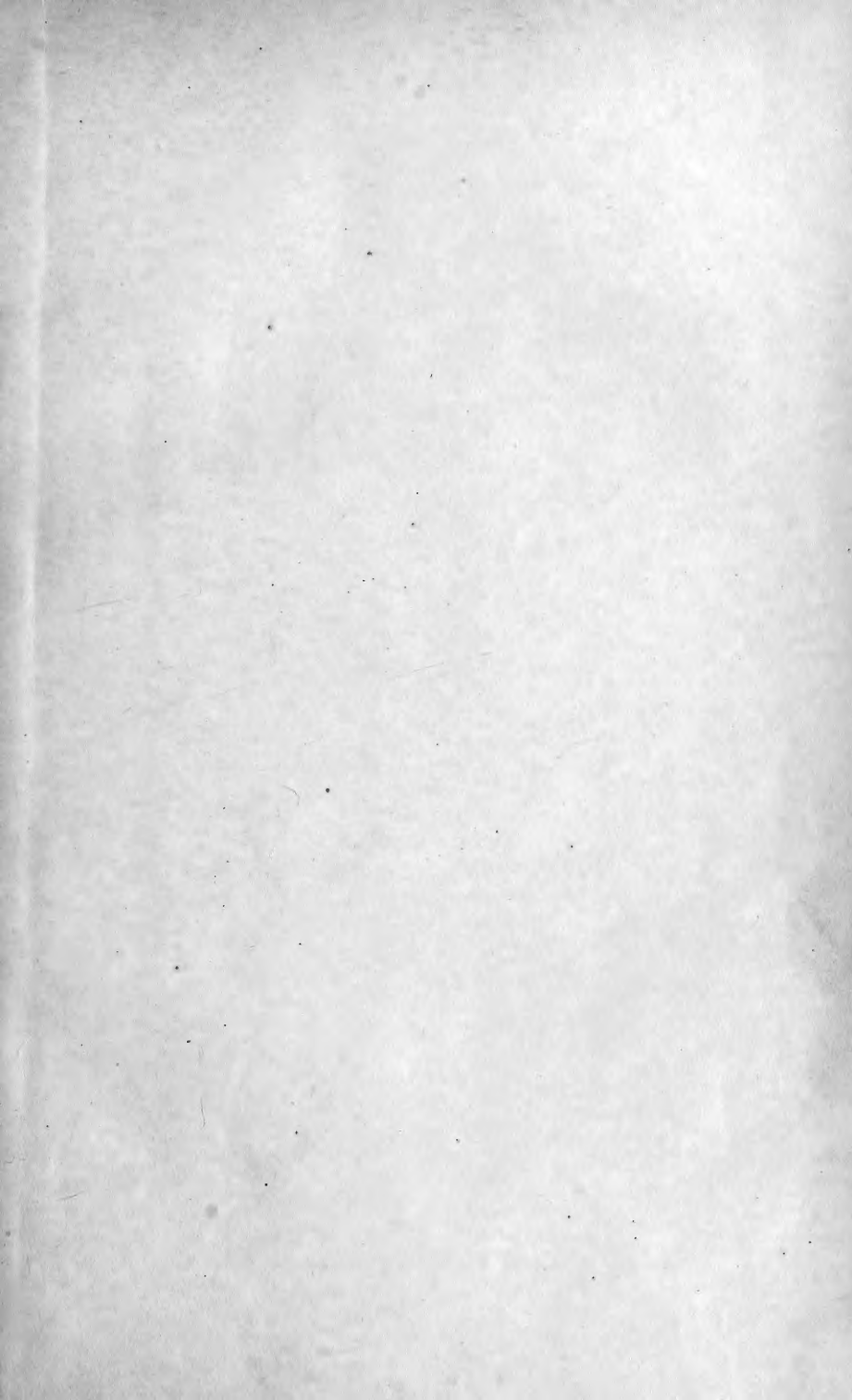




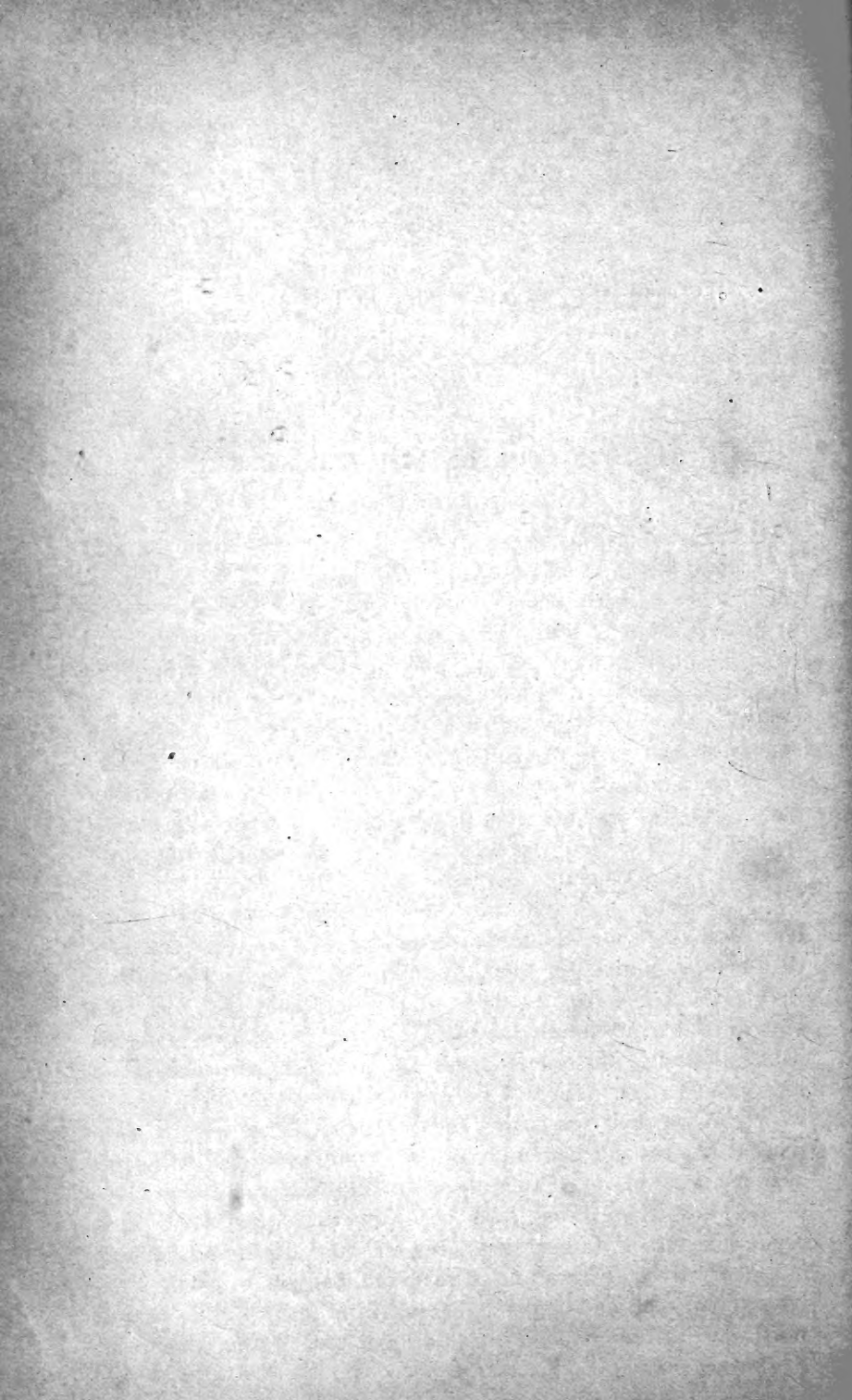
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BRAZILIAN CORALS AND CORAL REEFS.

BY RICHARD RATHBUN.

OUR first accurate information regarding the character and extent of the Brazilian coral reefs, as well as of the sandstone reefs, dates from the earlier explorations of the late Prof. Hartt in Brazil. Prior to the publication of his general work, referred to in the June number of this journal, there existed only a few imperfect notices of corals and coral banks on the Brazilian coast. Spix and Von Martius, during their South American travels in the early part of this century, discovered patches of living and dead corals at several localities along the sea coast of Bahia, but they did not stop to fully investigate them or extend their observations, and the corals they collected were erroneously referred to old Lamarckian species.

Darwin, who touched at the Abrolhos islands, saw corals growing upon the shore, but overlooked the vast and curious reefs that occupy so much of the surrounding region. On the authority of others, however, he states that around these islands "the bottom of the sea is entirely coated by irregular masses of corals, which, although often of large size, do not reach the surface and form proper reefs." In this he was partly right, but very largely wrong, as we shall see farther on. Darwin also refers to coral reefs at Maceio and Pernambuco, and Prof. Dana mentions a reef near the latter place. Other observers had increased the number of localities where coral reefs occur, so that when Prof. Hartt began his studies of these structures, we were already acquainted, in a general way, with a line of scattered, and often widely separated, coral reefs and banks extending from the Abrolhos islands northward to Maranhão. Our information respecting them was,

however, very meagre, and usually unreliable. Only a very few species of Brazilian corals were known, and these were mostly Gorgonians from the bays of Bahia and Rio de Janeiro.

The sandstone reef and coral reef regions of Brazil are nearly coëxtensive, but while the stone reefs are always confined to the immediate neighborhood of the shore, coral reefs frequently lie some distance out, at times forty or fifty miles. It was while investigating the stone reef at Porto Seguro, in 1866, that Hartt's attention was first attracted to the coral reefs, one of which stretches across the mouth of the bay of Porto Seguro, in front of the sandstone structure. This reef was carefully studied, and growing upon it were discovered all the commoner Brazilian corals. A year later Prof. Hartt visited the Abrolhos islands, for the purpose of examining the many reefs that cluster about that little group of Continental islets. The trip was a very successful one, resulting in the discovery of new and interesting phenomena in connection with the formation of coral reefs. Many corals were obtained, including all the species previously found at Porto Seguro, and these constituted the first large collection of Brazilian corals to be properly studied and described. The work of classifying this material was entrusted to Prof. Verrill, of Yale College, who decided that nearly all the forms were new to science.

Prof. Hartt's studies on the Brazilian coast have proved that Madreporian corals grow abundantly on or near the shore, from Maranhão southward to Cape Frio; south of which only a few Astrangians have been collected. Coral reefs are, however, more restricted in their range, as they do not pass to the southward of the Abrolhos region. Just to the east of the Abrolhos islands, between these islands and the mainland, and thence northward to near the city of Bahia, coral reefs are very numerous, often fringing the shores, but more commonly growing in large and irregular patches in the deeper water. From Bahia to Maranhão coral reefs are much less abundant, being confined to certain localities near the shore. The Rocas, between Fernando de Noronha and the coast, are, however, entirely of coral. The Brazilian coral fauna is very poor in species, but, as far as it goes, closely resembles that of the West Indies, many of its species being representatives ones. A large number of the commoner West Indian genera, such as *Madrepora*, *Mæandrina*, *Diploria*, etc., are wanting to Brazil.

Having thus briefly defined our present knowledge of Brazilian corals and coral reefs, let us proceed to study them more in detail, as they appear to one traveling through the regions in which they are contained.

Rocky shores, although usually of a tame character, are not uncommon in the coral region of Brazil, and they afford a proper footing for the growth of corals, both as scattered masses and in the form of reefs. The Bay of Bahia has quite a rich coral fauna, and presenting a varied shore enables us to study well the several littoral and shallow water species. As we enter the bay through its broad mouth, high cliffs of gneiss stand up before us on the right, but they soon give way to a low, and often nearly level shore of Cretaceous shales, sandstones and conglomerates, which, interspersed with beaches of sand, border almost the entire bay. Long stretches of rock lie under the influence of the tides, being entirely covered during flood, and exposed at low water. In addition to these, countless ledges exist everywhere off the shore, and being always submerged are better suited for coral life.

In the many tide pools of the rocky surfaces, and just below the level of low tide, live in abundance two of the most common of the Brazilian corals, *Siderastræa stellata* and *Favia graviga*. These two species are almost always associated together, and they range throughout the entire coral region above defined. The former is, however, the more abundant, and attains the larger size; it is also the more hardy species, and at low tide may be exposed to a burning sun for an hour or more without sustaining injury. The size and shape of these coral masses, as well as the general structure of their cells, often vary greatly, according to the kind of rock on which they grow.

If the shore be formed of shales, presenting a level surface but affording only an insecure attachment, the corallum will spread outwards rather than upwards, giving rise to a thin flattened mass which may be over a foot and a half across and less than an inch thick. A smooth sandstone surface gives a firmer foundation, and permits, as it were, a thicker growth, although the tendency is still toward lateral spreading. Shores of gneiss and conglomerate are, however, generally rough and jagged, pierced with irregular holes and beset with multitudes of rounded or angular projections. On such a surface the growth of flat and level coralla is impossible; they tend to rise in hemispherical or globular

masses, conforming more or less in size and shape to the projections from which they spring. This law of variation seems to hold good for the entire coast. A small species of *Porites* occurs at times, associated with the two species above named.

A little deeper down, where they can seldom, if ever, be uncovered by even the lowest tides, come in other and more showy corals. Mussas grow profusely at many localities, seeming to prefer the abrupt outer edges of the submerged rocks. They belong to two species, one with separated cells not now living in the Bay of Bahia, the other having the cells closely joined nearly to their summits. Occasionally we find small heads of *Orbicella* and *Acanthastræa* in similar situations, but these more commonly inhabit deeper water. The same may also be said of *Millepora*, the hydroid coral, of which there are two common and one rare species on the Brazilian coast; in very shallow water it is stunted in growth and usually bears only short branches. Living on the under sides of stones, in company with encrusting bryozoans, is a very small Astrangian, consisting of many widely separated cells united by thin creeping stolons.

An *Agaricia*, very rare in the Bay of Bahia but more common elsewhere, generally grows attached to some other coral, as, for instance, to the dead base of *Mussa*. On the coast of Pernambuco there is also a small *Stylaster* attaching itself in the same way. *Pectinia braziliensis* is seldom found adhering to a rocky surface, but is very abundant at times in sheltered situations, partly buried in the mud. There remains only a single other Madreporian coral to mention here; it is the *Porites solida*, which seems to live nearly everywhere excepting in the Bay of Bahia.

This closes the list, with one or two exceptions of rare species, of the shallow water Madreporian corals of Brazil. The most of the species enumerated are very widely distributed, ranging along the entire coast north of Cape Frio. But they are not confined to the shore, for the majority also occur on the outer reefs, which are, so far as we know, entirely built up of a few of these same species. From depths ranging from twenty-seven to forty fathoms were procured several small corals; but these forms can, at the most, play only a very insignificant part in reef-building.

Let us return, however, to our studies in the bay. Five or six species of Gorgonians are abundant nearly everywhere, growing as commonly from small stones and dead corals imbedded in the

sandy and muddy bottoms, as from the rocky surfaces which afford them a more secure foundation. Two or three additional forms have been found along the coast; but the soft nature of these corals does not permit of their entering into the structure of a reef, excepting as their minute spicules may be added to the calcareous sand or mud, a very important element in the formation of coral reefs.

We pass now from the corals proper to other organisms, that give rise to quite as durable a substance of the same chemical composition. These are among animals the *Serpulæ* and *Barnacles*, and among plants the *Nullipores*. They grow abundantly on the shore, forming encrusting layers or thickened masses; but we have treated very fully of these forms on page 352 of this journal, in connection with the sandstone reefs. The thin encrusting nullipores, with nearly smooth or slightly mammillate surface, which cover so much of the Pernambuco reef, inhabit also many of the rocky shores, but are more abundant over several of the coral reefs that have reached too high a level for the growth of true corals. There is another common nullipore, composed of many intermingling and closely placed branches, which project outwards in all directions as numerous digitations. This form grows to an immense size at times, and is associated with the corals in reef-building. A coarsely jointed coralline forms large and dense clusters on the coast of Pernambuco, and its detached segments sometimes form quite a thick deposit, especially on the surfaces of reefs.

The limestone-producing fauna and flora we have thus hastily reviewed, may not differ in their essential features from those of all the other coral regions in the world, but it has seemed best to treat of them as fully as we have, in order to show more clearly how few are the species of Brazilian corals, particularly those that can aid materially in the building up of reefs. Up to this time but thirteen species of Madreporian corals, representing ten genera, have been found on or about the Brazilian reefs, and of these only three or four ever attain to any considerable size. Millepores have also contributed largely to the coral reefs.

We have now to trace the gradual variation in coral growth as we proceed outward from the shore toward the reef grounds. Here is a rocky ledge, reaching to within about a fathom of the surface at low tide. It is of small size, only a dozen feet each

way, but it affords a good base for corals to grow upon, and the ebbing and flooding of the tides produce about it a constant current of the purest sea water. No locality could be more favorable for marine life. As we approach in our canoe, the first objects that appear are the millepores, sending upward from their shapeless bases the most irregular and fanciful forms, generally in the shape of broad leaves or of ramifying branches ending in finger points. So wild and luxuriant is their growth at times that they partly cover up and obscure the lower-lying heads of more solid corals. But scattered everywhere between them, and over the edges of the ledge, are huge heads of *Orbicella*, *Acanthastræa* and *Siderastræa*, while *Mussas* and *Porites* also occur. Other of the shore corals are there too, but from their small size escape our notice in this hasty examination. We see only those larger forms that stand prominently forward, and thus proclaim their great importance in the building of durable structures that may last for all eternity.

This little group of corals, surmounting the rocky ledge, forms a miniature reef; it has only to build upward as far as the water will allow, and fill in the open spaces either with additional growths or with hardened coral sands to possess a true reef structure. Now prolong the ledge with its living top; let it stretch away for several miles and be broadened out to as many yards, and we have a reef such as occurs at times on the Brazilian coast. Unless the coast is sinking the reef soon attains its height and ceases to grow on top, but it may still continue to increase in width. Several of the Brazilian reefs are exactly of this character, having very little height, but from the surface looking like very massive structures. A broad area, presenting favorable conditions for growth, sometimes results in the formation of a wide and irregular coral bank, but such are not common near the shore.

We might now enter into a discussion of the many fringing and other reefs that lie along the coast; but they are all more or less repetitions of one another, are formed in similar ways, and composed of the same corals we have been describing. They are very many in number, occurring in all favorable localities, especially on the coast of Bahia, south of the capital. There is one reef, however, that derives a special interest from the accurate view of it we are able to give, and having been partially raised



Coral Reef of Bay of Bahia.



above the water its growth is nearly finished, so we can trace its entire history from the beginning to the close.

The long island of Itaparica, often called the garden of Bahia, fills up almost the entire south-western quarter of the large Bay of Bahia, and contracts its entrance to a width of about five miles. Its outer coast, running obliquely, faces for the most part the open sea, and is at the mercy of its boisterous waves. Skirting the central portion of this coast for a distance of nearly nine miles, is a slightly elevated coral reef, long since abandoned by true living corals and given over to another class of workers, who are putting on the finishing touches and coating it with a hard and durable substance.

This reef begins directly opposite the city of Bahia, in front of a little rocky point named Jaburú, and stretches away southward, in the general trend of the shore, enclosing behind it a narrow and shallow channel which, at the most, is scarcely one-fourth of a mile in breadth, and generally less. It is most perfect toward the northern end, and has, at irregular intervals, numerous breaks or openings which admit the smaller boats that ply along the shore. Approaching close to Peña, another rocky point about three miles from Jaburú, it ends abruptly; but commencing again just to the south, it runs onward to the Ponte da Cruz, terminating for good on the rocky shore. The study of the geology of the island has shown that the reef follows the submerged, outcropping edges of a series of heavy beds of sandstone, which, at times, bring up on the shore in the form of rocky points. On this solid base the reef appears to have been built, and where, finally, at the south, the sandstone leaves the sea and lies upon the beach, the coral reef ceases to exist.

The reef is slightly zigzag in its course, and both edges are very jagged, deeply indented and bordered by projecting or out-lying masses; but so irregular is every part that it would be quite useless for us to try and describe it accurately. At the northern end it is generally elevated on the outer side and low and level on the inner. The higher portion varies greatly in width and height, and is never flattened on top; it rises rapidly, often abruptly, from the water, but descends more gradually on the inner side to a level of about one foot above ordinary low tide. From here there extends inward a very flat surface, which is generally quite broad but may narrow down or even nearly disappear.

Almost everywhere along the inner edge, but more commonly at the ends of the reef and about the openings through it, we find many outlying masses which are often partly continuous with the low, inner surface, but more frequently quite detached. They attain all heights up to that of the lower surface, but never reach above it; the average depth of water around them is between three and four feet. The outliers on the outside of the reef are merely low, ragged, angular projections from the reef itself, and are never much exposed, even at low tide.

Between the two divisions of the reef, the elevated outer portion and the flat inner one, there is the most marked contrast. While the latter has been completely smoothed and rounded off, so that scarcely any angles remain upon it, the former retains all the possible roughness that could be brought together on so narrow an area. The entire raised mass of rock is full of holes of every imaginable size and shape, the margins of which are always acutely angulated. Every little surface that is not pointed in itself is surmounted by a large and strong barnacle with sharply-edged valves, and large clusters of digitate projections stand up at frequent intervals. This combination of surface is a very uninviting one to look upon, but it is far less pleasant to climb over it or walk along its upper part. The outer slope is by far the most irregular, as the waves, aided by an army of sea-urchins, have broken into it and hollowed out thousands of ragged holes, which, lying concealed beneath the seaweeds, might lead to many accidents were the reef more frequented.

The outer portion of the reef is of a dark and rather rich brown color when wet by the waves, but nevertheless has quite a dead appearance. Examining carefully this brown rock, it is seen to consist generally of an accumulation of very small worm tubes, closely packed together and forming a very hard mass. The surface of the low inner level is of a much lighter color, a rather faded brown, and looks even more lifeless than the part we have been describing; no barnacles or other large animals grow upon it.

What forms of life occur about the reef? On the outer side, reaching to a height of a foot or slightly more above ordinary low tide, is a luxuriant growth of seaweeds. Over the same zone, but not so apparent, spread encrusting nullipores, which, though resembling lichens in form, are so highly charged with lime as to

produce a hard coral-like substance. This is one of the most important organisms living on the reef at present, and while aiding to protect it from wear is also building it up. The barnacles and worm tubes of the upper portion we have already referred to, and we have also stated that over the inner surface there seems to be nothing alive. As we enter the many open pools and passage ways of the inner margin there is scarcely more to be seen. Only here and there does a small mass of coral grow, usually a *Siderastræa* or a *Favia*. Seaweeds and delicate tufted hydroids and bryozoans hang from the sides of the pools, and a few shell-fish and star-fish lie on the sandy bottom. Small, brilliantly-colored fish dart hither and thither, but the life is not what we are taught to expect about a coral reef.

The features we have so far been giving are those of the northern section of the reef. Going southward a short distance, the elevated outer mass gradually diminishes in size, until it is reduced to a slightly raised border along the seaward margin of a broad and flat reef. Still farther south the entire lower surface, without the raised margin, seems lifted bodily upwards to form a high massive wall, like that of an immense fort, flat above and perfectly square at the sides.

Between the points of Peña and Cruz we find a varied structure, generally, however, only a repetition of the forms already described. The reef is often two or three times as broad as at Jaburú, but near its southern end it becomes very irregular and much broken up, existing as a line of detached reef masses. The passage ways through the reef are sometimes mere simple breaks, cut as squarely and neatly as though the work of man; at other times, however, the edges of the reef bordering them are carried obliquely inwards some distance toward the beach, enclosing a narrow entrance channel. These inner prolongations, although generally low and level, have the same structure as the main reef.

Within the reef the water is always shallow; frequently the bottom lies so high as to be quite exposed at low tide, and it is covered nearly everywhere by a thick deposit of coral fragments, cemented together by carbonate of lime. The corals are not in place but lie heaped together in every conceivable way, as though they had been violently broken from the reef at some former time and thrown inside by the waves. All the commoner forms are there, *Millepora*, *Siderastræa*, *Orbicella* and *Mussa* being the

most conspicuous, and they are sometimes nearly perfect, but most often broken into irregular masses, large and small. The majority are also coated over with a thin nullipore crust, as though they had been dead a long time before they were swept from their proper dwelling places. This coral deposit has considerable thickness near the middle of the channel and thins out gradually toward the beach.

The extreme southern end of the reef is very low, and near to the beach. It breaks down abruptly on the outer side, but on the inner is bordered by a thick, consolidated layer, which reaches so nearly its own level that it is often difficult to make out the dividing line between the two. A close examination, however, discloses the upright corals in the one and the prostrate fragments in the other.

A great difficulty stands in the way of our determining the intimate structure of this nearly extinct reef, whose outward appearance and surroundings we have so fully discussed. It has evidently not been formed entirely by those agents at present occupying its upper and outer surfaces; but the remains of the real builders, whatever they were, are now entirely covered up and hidden from view, excepting at the one point at the southern end just mentioned. We must resort to artificial sections, no easy undertaking in a coral reef.

Breaking with hammer and chisel into the higher part of the reef, we obtain specimens of a very hard, compact limestone, partly of a nearly homogeneous structure, partly marked by straight or wavy lines of lighter and darker coloring; these two kinds of structure are intermingled with one another without order, sometimes one, sometimes the other predominating. The former has resulted from the masses of serpulæ tubes—by the complete filling in of their winding cavities and the spaces between them by carbonate of lime, until no trace of the original structure remains. The latter is due to the growth of incrusting nullipores, one thin layer upon another, until quite a thickness of rock has been the result.

It is evident that serpulæ and nullipores were at one time living together over the surface of the reef, and by their combined action has been formed most, if not all, of its outer raised portion, which is sometimes over four feet high and twenty-five feet across. The barnacles are generally broken from the reef when

dead, but are sometimes overgrown by worm tubes and thus become imbedded.

Here and there, the slaves in procuring limestone, have quarried into the low inner part of the reef, and even into the high wall-like portion. Good sections for study are thus formed, and they tell us of what the reef consists. Many large heads of *Orbicella*, *Acanthastræa* and *Siderastræa* stand there exposed in their original positions, and when cut through show their structure to be as open and perfect as though they were still living. With them are many large millepores and nullipores, and all the intervening spaces are filled in with a compact calcareous substance.

Our structure began as a true coral reef, stretching along the submerged rocky ledge. The water was very shallow, however, and the reef soon reached a level above which its corals could not live. Over them nullipores began to grow, but probably while the reef was being raised by other causes than those of growth, large numbers of these dead and partly entombed corals were swept inward by the waves. Nullipores continued to thrive and serpulæ came in to aid them, but with these forms we are already familiar.

Under certain conditions corals begin to grow in scattered patches over the sea bottom, and build up columnar masses which may eventually reach the surface. These columns vary in diameter from two or three feet up to several yards; they are very irregular on top, and covered with living corals. Such structures frequently occur near the shore, generally along the margin of a fringing reef; but their true habitats—where they are best developed—are in the deeper waters of the Abrolhos region, and between there and the city of Bahia. They have also been recorded from Florida and other parts of the world, but on the Brazilian coast they are a much more prominent feature, composing nearly all the larger reef patches.

As one of these coral pillars approaches the surface of the sea, the tendency to upward growth is necessarily destroyed, and the corals living only at the sides build out a rim about it. A mushroom or umbrella-shaped structure, called by the Brazilians *chapeirões*, or big hats, is thus produced. If many such chapeirões occur near together, their ever enlarging rims finally meet, resulting in the formation of a connected reef surface, supported by many upright pillars underneath.

Prof. Hartt, in his "Geology of Brazil," already quoted, has

very fully described the various Brazilian reefs formed by chapeirões, and there is little new to add; but we will take a hasty glance at them in order to complete our sketch. The Abrolhos islands lie some forty miles from the coast, near the middle of the submerged continental plateau, in about latitude  $18^{\circ}$  south. Surrounding them is a very extended area of constantly warm and pure water, everywhere less than a hundred feet deep. Just to the eastward of these islands is a region, nine or ten miles long and about four broad, over which the pillar-shaped structures are thickly scattered, forming the well-known *Parcel dos Abrolhos*. The chapeirões occur here of all heights and sizes, but never reach the surface, or coalesce to form a continuous reef.

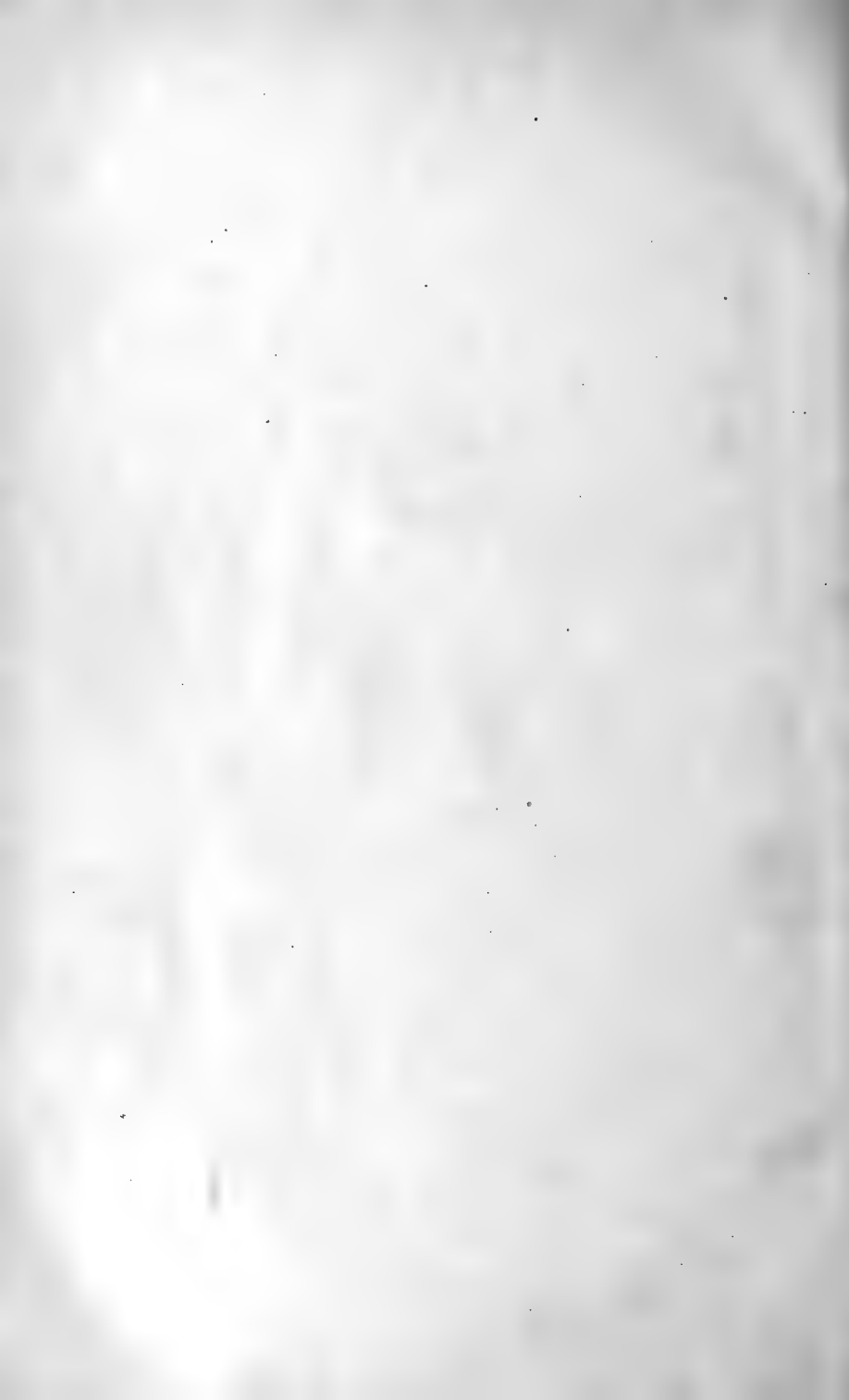
To the north-west of the Abrolhos, and reaching much nearer to the mainland, is the largest reef region of the Brazilian coast, called the *Parcel dos Paredes*, or *Shoal of the Walls*. It is irregular in outline, being about seventeen miles long from north to south, by about nine miles broad in the widest place. Within this area are extensive connected reefs, as well as multitudes of scattered chapeirões. The northern part of the Parcel forms one immense reef, reaching slightly above the level of low tide and formed by the growth of large coral patches and by the coalescing and filling in of chapeirões. This latter feature in reef building has been noticed only on the coast of Brazil. The edges of the reef are very irregular, but the upper surface, laid bare at low tide, is of quite uniform height, although marked by many scattered shallow pools. Running along the margin of this level portion, and separating it from that which is constantly submerged, is a slightly raised border, a foot or less in height, formed by the growth of nullipores, serpula tubes and barnacles. At low water the waves beat against this hard rim, which thus helps to protect the upper part of the reef from wear. The submerged border of the reef dips gently for a certain distance, and then breaks down abruptly to a depth of three to ten feet, meeting a bottom of soft, bluish, calcareous mud which slopes rapidly away, soon attaining a depth of seventy to eighty feet. Chapeirões surround much of this large reef, and extending off southward from it, form two other reefs, the *Recife de Leste* and *Recife da Pedra Grande*, comprising the rest of the *Parcel*.

Several other reef patches, resulting from the growth of chapeirões, occur between the Abrolhos islands and the mainland, and also farther north along the coast of Bahia.

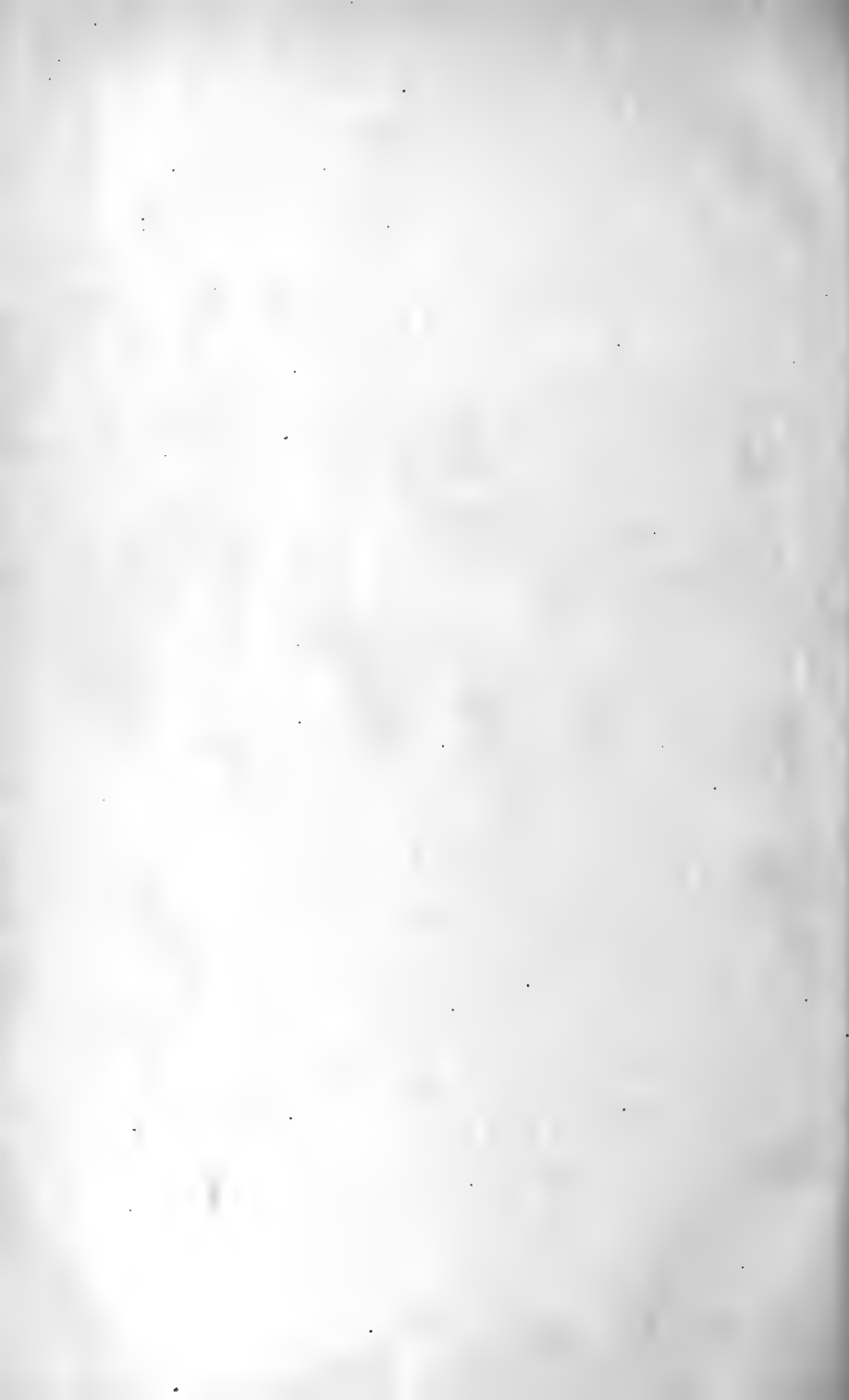




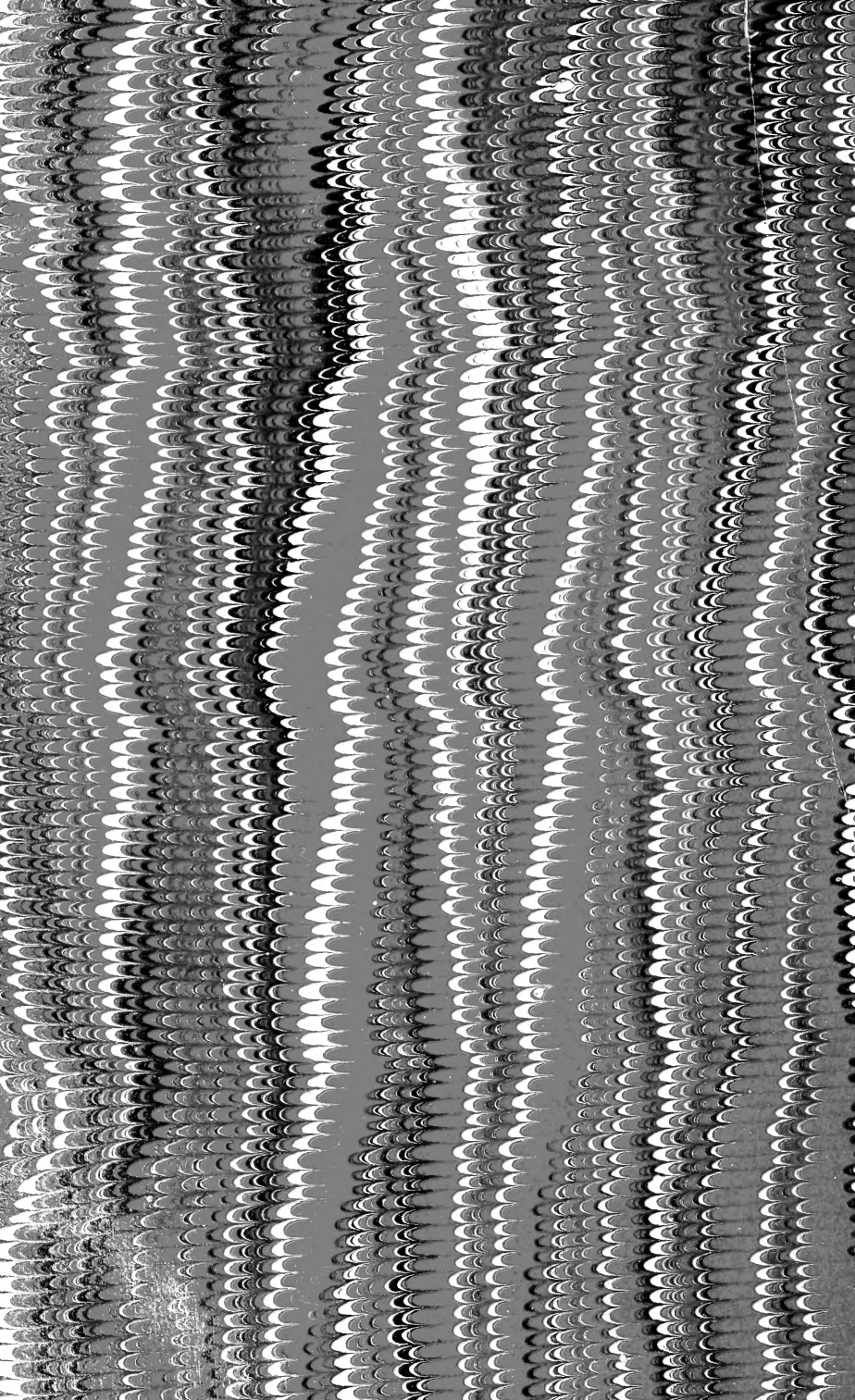


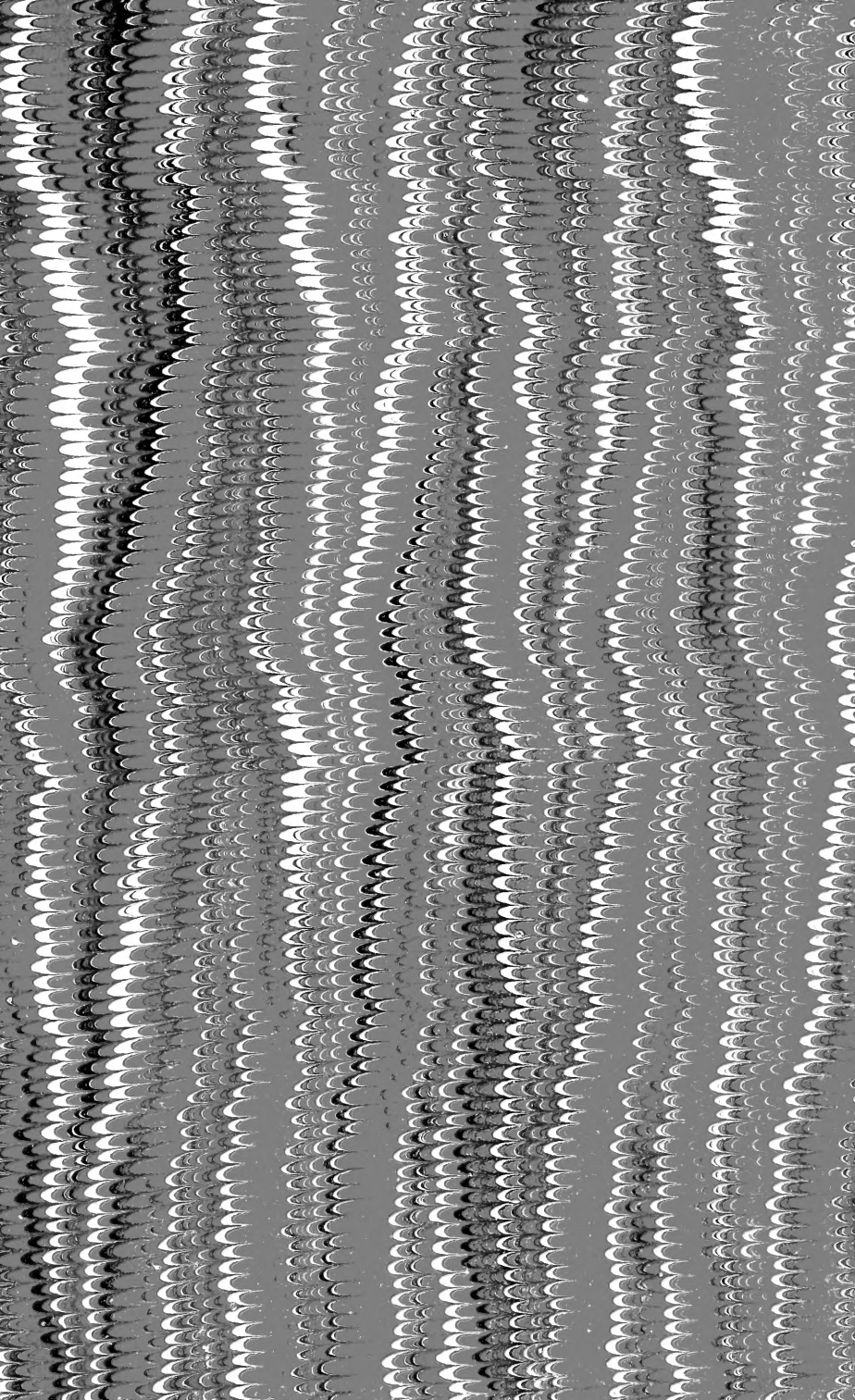














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